Efficacy of hunting for managing a suburban deer population in eastern Nebraska

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Abstract The Fontenelle Forest (FF) Nature Area maintained a "hands-off" management policy for 30 years, when it was recognized that a burgeoning population of white-tailed deer (*Odocoileus virginianus*) was severely degrading native plant communities. In 1995 members of a community task force implemented annual 9-day hunting seasons on FF after we showed that deer densities exceeded 28 deer/km^2. To better understand the impacts of the hunts on the deer population, we documented movements, seasonal home ranges, and survival of 51 female deer by radio-telemetry during 1995-1998. Archers harvested 85 antlerless deer in the FF upland area, adjacent to residential Bellevue, Nebraska, during 1996-1998. Muzzleloader hunters removed 53 antlerless deer from the FF lowland area. Archery and muzzleloader hunters harvested 297 deer during the same period in Gifford Point (GP), a state-owned wildlife management area adjacent to the FF lowlands. Overall deer densities declined from 28 deer/km^2 in 1995 to 14 deer/km^2 in 1998. Densities were at or near over-winter goals in all areas by 1998, except for the unhunted residential area, which still maintained 20 deer/km^2. Hunters harvested 39% of the radio-marked deer. Annual survival rates for radio-marked adult and yearling female deer were 0.70 and 0.59. Archery hunting was the primary mortality factor (20%) for radio-marked deer across years. Population models predicted that densities would increase to 55 deer/km^2 in 5 years if hunting was discontinued in FF. The manipulation of deer survival through regulated hunting has proven effective for deer population management in the Gifford Point and Fontenelle Forest area (GP-FF). Regulated deer hunts should be continued in the FF upland and lowland areas to maintain annual deer density at or near an established over-winter goal that promotes the preservation of native plant communities and provides for viewer recreation.

Key Words archery, hunting, muzzleloader, *Odocoileus virginianus*, radiotelemetry, suburban, white-tailed deer

White-tailed deer (*Odocoileus virginianus*) were nearly extirpated from Nebraska in the late 1800s (Menzel 1984). The first deer in recent history on Gifford Point and Fontenelle Forest area (GP-FF) were observed in the early 1960s (Gary Garabrandt, unpublished report). By 1964, deer were causing noticeable damage to crops on Gifford Farm (GF). That same year the first rifle hunt was conducted on GP to reduce the population. Successive archery and muzzleloader hunts were conducted on GP and annual harvests averaged 120 deer. A fixed-wing aerial census in February 1982 yielded a count of 158 deer (estimated population of 200 to 350 deer), of which 97% were located in the floodplain forest east of the railroad track that separated the upland and lowland portions of the study area. In the late 1980s, either the deer population increased dramatically, or deer shifted their home ranges into the wooded hills of FF and adjacent suburbs, or both.

Managers at GP-FF became concerned about the perceived overabundance of deer during the late 1980s. By this time, continuous browsing of woody shrubs and sapling trees by deer resulted in a browse line throughout the forest and herbaceous vegetation was in poor condition. In 1992 it was

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brought to local and national attention that overabundant white-tailed deer were degrading the forest of FF and causing "reverse succession" (Diamond 1992). At this time the deer population in GP-FF was estimated to be 600-800 and GF (which is on GP) reported $15,000 in crop losses due to deer damage, and a record 193 deer were harvested on GP. Also, deer-vehicle collisions in the surrounding area increased 300% from 1984 to 1994.

A Deer Task Force was established in 1994 to address these issues. It consisted of the stakeholder representatives from the surrounding communities who shared concerns about the growing deer population and associated problems. The Task Force provided a forum for all to express their points of view, evaluate research results, review land-use practices, and discuss deer management options. The members recognized the need and provided support for our research. With no reliable estimate of deer density, management strategies were limited and vulnerable to public criticism. Therefore, our first objective was to estimate the density of deer at GP-FF. We also estimated the population sex and age structure, determined levels of cause-specific mortality, and calculated annual survival rates. All of these variables were incorporated into a dynamic population model to estimate future deer population densities given various harvest scenarios. Our study was approved by the University of Nebraska Institutional Animal Care and Use Committee (#95-02-007).

Study Area

The 18.2-km^2 (7-mi^2) study area was adjacent to the Missouri River in northeastern Sarpy County, Nebraska, bounded to the north and west by Omaha and Bellevue, Nebraska. It consisted of 7 group or publicly owned parcels and several individually owned residential tracts. The Nebraska Game and Parks Commission managed the 567-ha (1,400-ac) GP Wildlife Management Area, which was located on the forested Missouri River floodplain. The Educational Services Unit #3 managed the 163-ha (400-ac) GF, which served as a center for agricultural education for the area's public school system. Corn, soybeans, and alfalfa were the primary crops raised on GF. The FF was a 526-ha (1,300-ac) nature preserve that consisted of roughly equal proportions of forested floodplain and wooded uplands. The area was traversed by 27 km (17 mi) of hiking trails. Public recreation and environmental education were the primary activities on the area. Camp Brewster and Camp Wakonda were 40-ha (100-ac) and 12-ha (30-ac) parcels located in the wooded upland, managed by the Young Women's Christian Association and Boy Scouts of America, respectively. To the north, the City of Omaha managed 28-ha (71-ac) Mandan Park and 13-ha (31-ac) Mount Vernon Gardens. To the south, the Nebraska Public Power District owned 6 ha (15 ac) of wooded lowland and the City of Bellevue managed a 5-ha (12-ac) wooded park. Several Bellevue residential developments, individual homes, and a golf course were interspersed with the upland forest and occupied about 400 ha (1,000 ac). The residential area sloped westward into an urban business-industrial area that bounded the study area. In addition, we included the western edges of Mills and Potawattamie Counties, Iowa in the study area. The primary land uses in Iowa were high-intensity agriculture and scattered municipal and residential developments.

Predominant plant communities included mature floodplain forest, forested river bluffs, upland suburban forest, and cultured turfgrass. The area also included floodplain agricultural fields, successional grassland savannas, and old-channel wetlands. Dominant tree species in the forest communities included cottonwood (*Populus deltoides*), silver maple (*Acer saccharinum*), sycamore (*Plantanus occidentalis*), bur oak (*Quercus macrocarpa*), red oak (*Q. rubra*), bitternut hickory (*Carya cordiformis*), and American linden (*Tilia americana*). Understory species included American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), hackberry (*Celtis occidentalis*), ironwood (*Carpinus caroliniana*), white mulberry (*Morus alba*), roughleaf dogwood (*Cornus drummondii*), and tree-of-heaven (*Ailanthus altissma*). The ground layer was occupied by over 350 species of forbs, grasses, and sedges.

Methods

After obtaining an initial population estimate of deer throughout the study area, deer hunting was initiated on FF during fall 1996 and consisted of a 9-day archery season in the FF upland area (including Camp Waconda) and a coinciding 9-day muzzleloader season in the FF lowland area. Hunting seasons on FF remained the same each year throughout the study. Deer hunting seasons on GP were managed the same as they had been before the initiation of our research. There was an annual fall 107-day archery season and a 9-day muzzleloader season.

Population estimation

We conducted a helicopter census of deer during the winters of 1995, 1997, and 1998. The entire study area was systematically flown at <50 km/h

(<30 mi/h) and the same flight pattern was followed for each census. To avoid flushing deer and disturbing area residents, transects were flown at about 53 m (175 ft) over the floodplain, 76 to 91 m (250 to 300 ft) over the upland forest, and about 91 m (300 ft) over the residential area. Two observers spotted deer while another recorded deer numbers and locations on a map. The same pilot and observers conducted the census each year.

Buck:doe and doe:fawn ratios

We determined fawn recruitment on GP-FF through multiple counts (70 to 80) of does and fawns from August to October, 1995 and 1996 (Nixon et al. 1991, Hansen et al. 1997).. Counts were conducted by 1 or 2 observers during crepuscular periods and at night. Binoculars, spotting scopes, and spotlights were used to facilitate observations. We completely covered the study area during each count, and followed the same route each time. Fawns were differentiated from their dams by size and behavior (Downing et al. 1977). We also recorded multiple counts (25 to 40) of adult bucks and does during the same period. Adult bucks were identified and differentiated from does they accompanied by behavior and the presence of antlers.

Mortality

We captured 99 deer from March 1995 to March 1996, primarily with netted-cage traps (VerCauteren et al. 1999). We radio-marked 51 females and 2 males (21 adults, >12 months old; 32 juveniles, 8-12 months old) with collars labeled with our return address. We marked 46 males with colored and numbered eartags. Our telemetry efforts focused on females because: (1) deer adopt matriarchal social family groups that are led by adult females and these groups make up the largest proportion of the population (Porter et al. 1991, Mathews and Porter 1993, Aycrigg and Porter 1997) and (2) knowledge of female survival dynamics is important for understanding and predicting population changes (Porter et al. 1991, Mathews and Porter 1993, Aycrigg and Porter 1997, Hansen et al. 1997).

Forty-eight of the transmitters were equipped with mortality sensors (Advanced Telemetry Systems, Isanti, Minnesota, USA and Wildlife Materials, Carbondale, Illinois, USA) that triggered when the transmitter was stationary for about 6 hours. We determined the cause of mortality for radio-marked deer as soon after death as possible, usually within 2 days.

At the end of the study we classified each radio-marked deer as alive, dead, or censored. Censored individuals were those whose fates were unknown (Van Deelen et al. 1997). We further classified mortalities as due to archery, firearms, automobile, train, epizootic hemorrhagic disease (EHD), predators (coyotes and domestic dogs), starvation, other (fence entanglement and poaching), and unknown. We used MICROMORT software to estimate survival and cause-specific mortality rates from the number of radio-days each marked individual survived during the study period (Heisey and Fuller 1985). We calculated annual survival rates for adult and yearling does with an annual period from 1 June to 31 May.

We used 2-tailed Z-tests to determine that annual adult survival did not differ across years (P = 0.11, n = 3 years) so we pooled the data. Yearling survival was also not different across years (P = 0.14, n = 2 years) and was pooled. Data for adults and yearlings were significantly different (P < 0.001) and could not be pooled. Pooling made sample sizes more meaningful, increased our confidence in comparisons, and provided a better indication of survival over time.

Population modeling

We used simulation modeling software (STELLA, High Performance Systems, Hanover, New Hampshire, USA) to develop an interactive population model. Our model was based on the general population model:

Table 1. Annual survival and cause-specific mortality rates of radio-marked does in the Gifford Point-Fontenelle Forest area, Nebraska, 1995-1997.

Age class	n[a]	Censored deer	Radio days	Deaths	Rate[b]	95% CI	Archery	Firearm	Poaching	Auto	Train	Natural	Unk.
Yearling	30	1	8,524	11	0.59	0.45-0.80	0.13	0.08	0.04	0.08	0.00	0.08	0.00
Adult	43	1	19.692	18	0.70	0.60-0.82	0.12	0.03	0.00	0.03	0.06	0.03	0.03

[a]Number of deer records from 1995, 1996 and 1997 pooled.
[b]Adjusted for small sample bias (Heisey and Fuller 1985).

$$N_{t+1} = N_t + N_t(b_t + i_t - d_t - e_t)$$

where N_t is population size (or density if divided by area) at time t and b_t, i_t, d_t, and e_t are per capita rates of birth, immigration, death, and emigration at time t, respectively. The initial female population was increased by annual births, as estimated by doe:fawn ratios. We limited the model to the female portion of the population because of the previously stated importance of female deer in the population, and because our radio tracking efforts focused on females we did not have adequate survival data from males. We did not collect data on immigration and assumed the immigration rate was near 0 due to the physical and ecological barriers surrounding GP-FF, deer sociobiology at high densities (Miller and Ozaga 1997), and source-sink dynamics (Meffe and Carroll 1994). We felt this was appropriate because of the high deer density on GP-FF as compared to adjacent areas. The population was decreased by cause-specific mortality and emigration.

We used mean annual estimates of demographic rates and density for females on GP-FF. For each demographic rate, we incorporated the same amount of variation in the model as we found in the field by including a function that randomly chose a rate within the 95% CI of the rate's mean. The model is an ongoing process driven by interdependent closed loops. Through simulation, we predicted the changes in population density for 5 years in response to varied harvest rates.

Results and discussion

Population estimation

Total counts of deer in the 18.2-km^2 (7-mi^2) study area in 1995, 1997, and 1998 were 495, 316, and 233, respectively. The deer, when flown over during the first 2 censuses, typically stood up from their beds but did not flush. The observers felt that their count was representative of the total number of deer in the study area. During the third census, ground visibility was impaired because of blowdowns from a storm in late October 1997. Therefore, we used our biological intuition to adjust the 1998 census data by +10% (256 total) to account for deer that may have not been counted. Adequate snowcover is the most important factor for an accurate aerial survey (Gladfelter 1980), and there was 10 to 15 cm (4 to 6 in) of fresh snow present when we conducted our censuses. Two deer studies conducted in the Midwest using helicopters have reported detection rates of 78% (Beringer et al. 1998) and 99% (Stoll et al. 1991).

Relative deer densities during the 3 study years were 27, 17, and 14 deer/km^2 (71, 45, and 37 deer/mi^2), respectively. The goal of most wildlife agencies in the Midwest is to maintain overwinter deer population densities at 10 to 13 deer/km^2 (25 to 35 deer/mi^2), to provide sufficient hunting and viewing opportunities yet minimize crop damage complaints and deer-vehicle collisions (Menzel 1984). Clearly, the GP-FF deer population was well over these goals in 1995, but by 1998 had declined by nearly 50% and was near goal.

The deer were unevenly distributed throughout the study area during the 3 counts. The highest density, 45 deer/km^2 (116 deer/mi^2), occurred in the FF uplands in 1995. By 1998, the deer population in the FF uplands had declined by 74% (12 deer/km^2) to a level consistent with deer density goals. Hunters on FF in 1996 and 1997 harvested 67 female and 15 male deer, contributing to the dramatic reduction in the local population. Hunter behavior was observed to be excellent during both hunts (Gary Garabrandt, unpublished report). Public opposition to the hunts was minimal and media coverage declined considerably in 1997 and 1998.

The deer population in the GP lowland declined 48% over the 3-year study period. Flooding of lowland areas by the Missouri River in June 1996 increased emigration rates, and likely mortality rates, but regulated hunter harvest was the greatest factor influencing deer population levels in GP-FF and has been throughout the Midwest (Gladfelter 1984, Nixon et al. 1991, Hansen et al. 1997).

As of January 1998, all deer densities were within population goals, with the exception of the residential area of Bellevue, Nebraska (BR area), which was still at 20 deer/km^2 (51 deer/mi^2). Deer were not observed in the residential area until the 1980s, after which they appeared frequently in the uplands (Gary Garabrandt, personal communication). Respondents to a 1995 survey of the surrounding residential communities sponsored by the FF Association indicated that deer numbers were increasing and that they were seeing deer more frequently. Hunting has not been allowed in the BR area because of local ordinances and safety concerns. Deer densities and associated problems will likely continue to increase in the residential area unless actions are taken to reduce the population.

Buck:doe and doe:fawn ratios

Ratios varied considerably between 1995 (1 doe:1.5 fawns) and 1996 (1 doe:0.4 fawns). Such differences in recruitment can have dramatic impacts on subsequent population densities. Ratios at the nearby DeSoto National Wildlife Refuge (DNWR) were stable (1 doe:1.2 fawns) during both 1995 and 1996 (VerCauteren 1998). Our 1995 doe:fawn ratio was similar to, if not slightly higher than, those reported in Illinois (1:1.3, Nixon et al. 1991), Missouri (1:1.1, Hansen et al. 1997), and Michigan (1:1.3, Ozoga et al. 1994). Without experimental controls we could only speculate on why the GP-FF doe:fawn ratio in 1996 was so low. On 23 June 1996, the Missouri River flooded its banks and inundated much of the floodplain area for 2 to 3 weeks. Several deer abandoned their original home ranges and moved to higher ground (S. Hygnstrom and K. VerCauteren, unpublished data). The flood came shortly after fawning and likely added to fawn mortality. In addition, for 30 years, deer in the lowlands were dependent on crops produced on GP. It was common to see >200 deer in crop fields at night during the growing season. Adult does on high quality diets typically have higher reproductive rates than does on low quality diets (Verme 1965, Ozaga and Verme 1982). In August 1995, construction of a 2.4-m- (8-ft-) high woven-wire fence was initiated around 100-ha (250-ac) of cropland area in GP. The 5-km- (3-mi-) long fence was completed in April 1996. Even during the construction period, the fence had a noticeable impact on the distribution of deer in the GP lowlands, and many deer were excluded from an important food source (S. Hygnstrom and K. VerCauteren, unpublished data). Available forage in the lowlands was limited because of overbrowsing. The resultant low quality diets may also have contributed to the low reproductive rate in 1996.

The buck:doe ratios were the same for the GP-FF area (1 buck:2.9 does) in 1995 and 1996. The relatively low differentials between males and females are indicative of deer populations in which sex-specific mortality rates are similar. Deer harvest on GP, however, has traditionally been biased toward males and against females (Nebraska Game and Parks Commission, unpublished report). Harvest management strategies (i.e., buck only, either sex, or antlerless only) and hunter preference can alter the sex and age structures of a population. Even in unhunted areas, the mortality rates for adult males are higher than for adult females (Gavin et al. 1984, Jacobson and Guynn 1995), due to their poorer physical condition entering winter and increased susceptibility to predation (McCullough 1979). Increased harvest of adult females on GP could help maintain more balanced sex and age ratios because of the resultant reduced harvest of yearling males (<18 months old) and increased male natality (McCullough 1979, 1984; Jacobson and Guynn 1995). Further, increased adult female harvest may reduce emigration rates of yearling males (Holzenbein and Marchinton 1992) and lead to decreased juvenile female emigration when populations are at or near carrying capacity. Managers should consider the effects of management strategies on deer population structure, social behavior, and demography (Miller 1997). The annual mortality rate of females, and its impact on density, determines the response of the overall population, including the size and age structure of the buck population (McCullough 1984).

Mortality

Data on primary mortality factors, and their combined impacts on a population, are important in deer population management (Dusek et al. 1989, Fuller 1990). We included 50 (21 adults, 29 yearlings) radio-marked deer in the survival-mortality analysis. At the end of the study, 19 of the radio-marked females were still alive, 2 were censored, and 29 were dead. Annual survival rate of adult and yearling radio-marked females was 0.70 (CI = 0.60 to 0.82) and 0.59 (0.45 to 0.80)(Table 1). Annual survival rates for radio-marked females at the nearby DNWR were 0.76 for adults and 0.82 for yearlings. High annual survival rates for females (80% to 100%) also have been reported elsewhere in the Midwest (Nelson and Mech 1986, Fuller 1990, Nixon et al. 1991, Hansen et al. 1997, Van Deelen et al. 1997).

Human-related mortality factors (archery and firearm hunting, automobiles and trains) were responsible for the deaths of 83% and 79% of the marked deer in 1995 and 1996, respectively. Archery was the primary mortality factor (20%). A similar human-related mortality rate (82%) was determined for female deer during 1991-1997 on DNWR, where muzzleloader hunting was the primary cause of mortality (77%)(VerCauteren 1998).

Trains were a surprising cause of mortality in GP-FF and adult deer appeared to be more susceptible to trains than yearlings (Table 1)(S. Hygnstrom and K. VerCauteren, unpublished data). Adult does may have crossed the railroad tracks more frequently when trains were running or their home ranges may have overlapped the tracks more than yearlings. Automobiles killed only 3 marked deer (about 10%). Considerably higher deer mortality rates have been attributed to automobiles in other parts of the Midwest (30% in eastcentral Illinois and 13% in northcentral Missouri; Hansen et al. 1997), but traffic and road conditions differ in these areas.

Non-human or "natural" causes of mortality, including disease, predators, and starvation, were a minor source of known deer mortality during the study (14%, n = 4). Several other studies also have reported <25% of adult deer mortality was due to natural causes (Fuller 1990, Nixon et al. 1991, Hansen et al. 1997). Outbreaks of EHD occur infrequently throughout the Midwest when climatic conditions are favorable for disease vectors (Gladfelter 1984). The Missouri River Valley has a history of EHD and 30-40% of the region's deer population was lost in 1976 (Menzel and Havel 1977). A minor outbreak of EHD occurred on GP-FF in 1995 and killed 2 radio-marked females. Coyotes can be a major predator and scavenger of deer, selecting primarily for fawns, old, wounded, and dead individuals (Gladfelter 1984, Huebschman et al. 1997). Though no marked deer were lost to coyotes, we did document 7 kills in 1996. All kills were within the woven-wire deer fence that was being constructed around GF cropfields, leading us to speculate that coyotes used the incomplete fence as a barrier to aid in their hunting.

Population modeling

Density of adult females should remain relatively stable if demographic rates continue as they were during 1995 to 1997. Deer density will remain relatively static if hunter harvest rates are the same or increase to 25% higher than the harvest rates in 1995 through 1997. If the hunting seasons were discontinued, the density would increase exponentially, to 55 deer/km^2 (145 deer/mi^2) in only 5 years. If the harvest rate was reduced by 50%, then the density would increase, to 29 deer/km^2 (77 deer/mi^2) in 5 years.

The model that we used incorporated rates that varied relative to the stochasticity we found in the actual population. Our changing rates, however, may not have been as dynamic as reality, where they are constantly changing on temporal and spatial scales due to a variety of natural and human-induced factors. Annual rates of birth, immigration, death, and emigration affect population density and vary depending on several intrinsic and extrinsic factors (VerCauteren and Hygnstrom 1994). It is important for managers to consider the impacts of changing demographic rates on density.

Management implications

The survival of adult females in the GP-FF area was relatively high. Natural causes of mortality were of minor importance, with the exception of occasional EHD outbreaks and possible increased fawn mortality due to flooding. We attributed most deer mortality to human causes. The manipulation of deer survival through regulated hunting was the key to population management in the GP-FF area. Increased harvest of antlerless deer would reduce population densities (McCullough 1984, McNulty et al. 1997) and associated environmental and social problems. Regulated deer hunts should be continued in the FF upland and lowland areas to maintain the annual deer density at or near an established overwinter goal that promotes the preservation of native plant communities and provides for viewer recreation.

The deer population at GP should be managed at or near the level of maximum sustainable yield to maintain a high level of deer harvest and hunter recreation. Some caution should be exercised to avoid overharvesting deer in the area to avoid the possible consequences of additive mortality that could occur in the event of extensive flooding (especially during the fawning period) or outbreaks of EHD. Forest openings and old field areas in GP could be managed to maximize forage production to possibly lure deer from the FF uplands and BR area.

The next problem that should be dealt with in the GP-FF area is the overabundance of deer in the residential area. Officials of the City of Bellevue should explore options to curtail residents from feeding deer within the city limits. Several landowners in the residential area started feeding deer in the early 1990s and now some put out as much as 23 to 46 kg of feed per day (50 to 100 lbs/day) (K. VerCauteren, personal observation). Supplemental feeding can detrimentally concentrate deer use of habitat and natural forage (Doenier et al. 1997) and may enhance survival of local deer (Swihart et al. 1995). In addition, associations have been made between high deer densities, deer feeding, and the occurrence of chronic wasting disease and tuberculosis (Nettles 1997). Both diseases are contagious in deer populations and in some cases call for the eradication of the infected populations. Homeowners should be educated about the problems associated with deer feeding and options for preventing deer damage to their property (Hygnstrom and Baxter 1991, Craven and Hygnstrom 1994). If a public education program is ineffective, then ordinances that prohibit deer feeding may be necessary. Officials also should consider regulated hunts or other deer removal practices in open-space areas to reduce deer densities to levels consistent with overwinter goals that lead to the reduction of deer damage and deer-vehicle collisions. A public education program should be implemented to increase landowner awareness of registered deer repellents, practical exclusion methods, and deer-resistant plants for landscaping.

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Literature cited

Aycrigg, J. A., and W. F. Porter. 1997. Socio-spatial dynamics of white-tailed deer in the central Adirondack Mountains, New York. Journal of Mammalogy 78:468-482.

Beringer, J., L. P. Hansen, and O. Sexton. 1998. Detection rates of white-tailed deer with a helicopter over snow. Wildlife Society Bulletin 26:24-28.

Craven, S. R., and S. E. Hygnstrom. 1994. Deer. Pages D25-40 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, editors. Prevention and Control of Wildlife Damage. University of Nebraska Cooperative Extension, Lincoln, USA.

Diamond, J. 1992. Must we shoot deer to save nature? Natural History 8:2-8.

Deonier, P. B., G. D. DelGuidice, and M. R. Riggs. 1997. Effects of winter supplemental feeding on browse consumption by white-tailed deer. Wildlife Society Bulletin 25:235-243.

Downing, R. L., E. D. Michael, and D R. J. Poux, Jr. 1977. Accuracy of sex and age ratio counts of white-tailed deer. Journal of Wildlife Management 41:709-714.

Dusek, G. L., R. J. Mackie, J. D. Herriges, Jr., and B. B. Compton. 1989. Population ecology of white-tailed deer along the lower Yellowstone River. Wildlife Monographs 104.

Fuller T. K. 1990. Dynamics of a declining white-tailed deer population in north-central Minnesota. Wildlife Monographs 110.

Gavin, T. A., L. H. Suring, P. A. Vohs, Jr., and E. C. Meslow. 1984. Population characteristics, spatial organization, and natural mortality in the Columbian white-tailed deer. Wildlife Monographs 91.

Gladfelter, H. L. 1980. Deer population estimators in the Midwest farmland. Pages 5-12 *in* R. L. Hine and S. Nehls, editors. White-tailed deer population management in the north central states. North Central Section of The Wildlife Society, Urbana, Illinois, USA.

Gladfelter, H. L. 1984. Midwest agricultural region. Pages 427-440 in L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Hansen, L. P., C. M. Nixon, and J. Beringer. 1997. Role of refuges in the dynamics of outlying deer populations: two examples from the agricultural Midwest. Pages 327-345 *in* W. J. McShea, H. B. Underwood, and J. H. Rappole, editors. The science of overabundance: deer ecology and population management. Smithsonian Institution Press, Washington, D.C., USA.

Heisey, D. M., and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. Journal of Wildlife Management 49:668-674.

Holzenbein, S., and R. L. Marchinton. 1992. Emigration and mortality in orphaned male white-tailed deer. Journal of Wildlife Management 43:872-879.

Huebschman, J. J., S. E. Hygnstrom, and J. A. Gubanyi. 1997. Coyote food habits at DeSoto National Wildlife Refuge, Nebraska. Prairie Naturalist 29:99-110.

Hygnstrom, S. E., and W. Baxter. 1991. Deer damage control in Nebraska. Publication EC91-1773. University of Nebraska Cooperative Extension, Lincoln, Nebraska, USA.

Jacobson, H. A., and D. C. Guynn, Jr. 1995. White-tailed deer population biology. Pages 81-111 *in* K. V. Miller and R. L. Marchinton, editors. Quality whitetails: the why and how of quality deer management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Mathews, N. E., and W. F. Porter. 1993. Effect of social structure on genetic structure of free-ranging white-tailed deer in the Adirondack mountains. Journal of Mammalogy 74:33-43.

McCullough, D. R. 1979. The George Reserve deer herd: population ecology of a K-selected species. University of Michigan Press, Ann Arbor, Michigan, USA.

McCullough, D. R. 1984. Lessons from the George Reserve, Michigan. Pages 211-242 *in* L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

McNulty, S. A, W. F. Porter, N. E. Mathews, and J. A. Hill. 1997. Localized management for reducing white-tailed deer populations. Wildlife Society Bulletin 25:265-271.

Meffe, G. K., and C. R. Carroll. 1994. Principles of conservation biology. Sinauer Associates, Sunderland, Massachusetts, USA.

Menzel, K. E. 1984. Central and Southern Plains. Pages 449-456 *in* L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Menzel, K., and R. Havel. 1977. Surveys and management of deer. Pitman-Robertson Project W-

15-R-33. Nebraska Game and Parks Commission, Lincoln, Nebraska, USA.

Miller, K. V. 1997. Considering social behavior in the management of overabundant white-tailed deer populations. Wildlife Society Bulletin 25:279-281.

Miller, K. V., and J. J. Ozaga. 1997. Density effects on deer sociobiology. Pages 136-150 *in* W. J. McShea, H. B. Underwood, and J. H. Rappole, editors. The science of overabundance: deer ecology and population management. Smithsonian Institution Press, Washington, D.C., USA.

Nelson, M. E., and L. D. Mech. 1986. Mortality of white-tailed deer in northeastern Minnesota. Journal of Wildlife Management 50:691-698.

Nettles, V. F. 1997. Feeding wildlife...food for thought. Southeastern Cooperative Wildlife Disease Study Newsletter 13:2-3.

Nixon, C. M., L. P. Hansen, P. A. Brewer, and J. E. Chelsvig. 1991. Ecology of white-tailed deer in an intensively farmed region of Illinois. Wildlife Monographs 118.

Ozoga, J. J., and L. J. Verme. 1982. Physical and reproductive characteristics of a supplementally fed white-tailed deer herd. Journal of Wildlife Management 46:281-301.

Ozoga, J. J., R. V. Doepker, and M. S. Sargent. 1994. Ecology and management of white-tailed deer in Michigan. Research Project W-127-R-12. Michigan Department of Natural Resources Lansing, Michigan, USA.

Porter, W. F., N. E. Mathews, H. B. Underwood, R. W. Sage, and D. F. Behrend. 1991. Social organization in deer: implications for localized management. Environmental Management 15:809-814.

Stoll, R. J., Jr., M.W. McClain, J. C. Clem, and T. Plageman. 1991. Accuracy of helicopter counts of white-tailed deer in western Ohio farmland. Wildlife Society Bulletin 19:309-314.

Swihart, R. K., P. M. Picone, A. J. DeNicola, and D L. Cornicelli. 1995. Ecology of urban and suburban white-tailed deer. Pages 35-44 *in* J. B. McAninch, editor. Urban deer: a manageable resource? Proceedings of the symposium of the 55th Midwest Fish and Wildlife Conference, North Central Section of The Wildlife Society, 12-14 December, 1993, St. Louis, Missouri, USA.

Van Deelen, T. R., H. Campa III, J. B. Haufler, and P. D. Thompson. 1997. Mortality patterns of white-tailed deer in Michigan's Upper Peninsula. Journal of Wildlife Management 61:903-910.

VerCauteren K. C. 1998. Dispersal, home range fidelity, and vulnerability of white-tailed deer in the Missouri River Valley. Dissertation. University of Nebraska, Lincoln, USA.

VerCauteren K. C., and S. E. Hygnstrom. 1994. A review of white-tailed deer movements in the eastern Great Plains relative to environmental conditions. Great Plains Research 4:117-132.

VerCauteren K. C., J. Beringer, and S. E. Hygnstrom. 1999. Netted-cage traps for white-tailed deer. Pages 155-164 *in* G. Proulx, editor. Mammal trapping. Alpha Wildlife Research and Management, Sherwood Park, Alberta, Canada.

Verme, L. J. 1965. Reproductive studies of penned white-tailed deer. Journal of Wildlife Management 29:74-79.

VerCauteren, K.C. AND S.E. Hyngstrom. 2002. Efficacy of hunting for managing a suburban deer population in eastern Nebraska. Pages 51-58 in Robert J. Warren, editor. Proceedings of the First National Bowhunting Conference. Archery Manufacturers and Merchants Organization, Comfrey, Minnesota, USA.